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Report No. G-1607-01

FISCAL YEAR 1988 PROGRAM REPORT

Robert C. Stiefel
Director

United States
Geological Survey

State of Ohio
Water Resources Center
The Ohio State University

Report No.
G-1607-01

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Water Resources Center
The Ohio State University
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Robert C. Stiefel, Director

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ABSTRACT

Water is one of Ohio's most important natural resources, and the State has an adequate supply to meet its immediate needs. Most of Ohio's water problems are associated with water quality. Of primary concern are the sediments, nutrients and acids in the surface waters from urban, agricultural and mining areas, and the toxic and hazardous wastes that threaten the ground and surface waters. The focus of the 1988 State Water Research Program was directed at some of these needs. One project explored the design criteria for an innovative two-stage fluidized bed bioreactor in which the three major processes of cell immobilization, biodegradation, and biofilm control were combined in a single unit. This wastewater treatment process is felt to be a substantial evolution in the operational technology of bioreactor design and the successful completion of this project could result in the development of an innovative, reliable and considerably less costly wastewater treatment system. Another project's research was a cooperative effort with OEPA, ODNR and the Nature Conservancy in examining and assessing the potential institutional and legal constraints that might hinder the development of programs for the management of nonpoint sources of pollution. One project explored the potential impacts that interactions and reactions between herbicides and existing humic materials have on the fate and transport of herbicides as they move through the soils toward the groundwater table. Training was provided to ten students enrolled in seven disciplines in two universities in Ohio.

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WATER PROBLEMS AND ISSUES OF OHIO

Water is one of Ohio's most important natural resources. Ohio is bounded on the north by Lake Erie and on the south by the Ohio River and contains other extensive ground and surface waters.

Ohio has an adequate supply of water to meet its immediate needs. However, the combination of large, heavily industrialized urban centers; extensive agricultural activities; high volume coal production and large coal reserves; and the demands associated with new energy production continue to cause concern for water quality and water management.

In addition, extreme hydrologic events cause localized problems of both excessive water and water deficiencies at times.

Surface Water

The northern twenty-five percent of Ohio's area drains into Lake Erie, while the remaining area drains into the Ohio River. Runoff from Ohio's streams and rivers averages about 25 billion gallons a day. The state also receives nearly a billion gallons of runoff daily from the neighboring state of Indiana which drains through the Maumee River to Lake Erie; Ohio also has access to additional flows past its boundaries in Lake Erie and the Ohio River that total well over 150 billion gallons of water a day.

Last year, more than 16 billion gallons of water were withdrawn from Ohio's surface sources each day to meet the demands for municipal supplies; rural needs for domestic and livestock purposes; irrigation; and self-supplied industrial needs including cooling water for thermo- electric power generation. Each day these demands account for 60 percent of the available surface waters in the state's streams. Localized shortages develop only during certain dry seasons and periodic droughts.

The combined length of all the streams in Ohio approaches 44,000 miles, which means that there is approximately one mile of stream for each square mile of surface area in the state. In addition, there are more than 50,000 lakes, ponds and reservoirs within the state which have a combined surface area of 200,000 acres. About 6,700 acres occur naturally, while the remainder are man-made impoundments that range in size from small farm ponds to large multipurpose reservoirs.

The reservoirs in the state are used to provide water for many different purposes including municipal, agricultural and industrial supplies; stream flow augmentation; flood control; and recreation. No impoundments in Ohio, other than those on the main stem of the Ohio River, provide water for downstream navigation or hydro-electric power generation. However, there is extensive navigation on both Lake Erie and the Ohio River, and consideration is being given to the installation of low-head hydro-electric generators at several developed dam sites throughout the state.

Flooding is a major problem in Ohio and it affects both urban and agricultural areas. It has been estimated that nearly two million acres of land in Ohio are flood prone. This represents more than seven percent of the total area of the state and includes nearly four percent of those areas classified as urban regions. Average annual flood damages in Ohio vary from year-to-year but amount to several millions of dollars annually.

Ground Water

Ground water is an important part of Ohio's water resources. Ground water underlies most of the state but is predominant in the glacial drift in the northwest, in the ice-contact and outwash deposits in river valleys along the border of the glaciated areas, and in the bedrock of the western portions of the state. Ground water supplies are largest in the glacial valley-train deposits in those drainage basins which border the Ohio River including the Ohio, Miami, Little Miami, Scioto, Hocking and Muskingum Rivers. Well yields from these deposits often exceed 500 gallons per minute (gpm), while aquifers in the glacial drift in the northwest and west-central parts of the state produce yields between 100 and 500 gpm. Isolated aquifers in the northeast, northwest and southwest have yields between 25 and 200 gpm, while much of the northeast contains aquifers whose yield is between 5 and 25 gpm. With the exception of the valleys along the major streams, most of the aquifers in the area that is tributary to the Ohio River have yields less than 5 gpm.

Seventy-five percent of Ohio's 650 public water supply systems use ground water as their source. In terms of volume withdrawn, however, a lesser share of these supplies comes from ground water, almost a half billion gallons of ground water are withdrawn daily for public water supply purposes, while more than a billion gallons come from surface water sources. However, ground water supplies nearly 80 percent of the rural water needs in Ohio, 32 percent of the irrigation waters and 21 percent of the industrial water demands. Nearly one billion gallons of ground water are withdrawn in the state each day to meet these needs.

Water Quality

It is the quality of water, rather than its quantity, that is the more critical and limiting condition associated with the use of both ground and surface waters in Ohio. The ground waters of the state frequently have relatively high, natural mineral contents; but, except for a few local areas, most of these waters are free from man-related contamination. Most complaints are related to increased levels of turbidity, bacterial populations and other substances from improperly sited or poorly constructed or maintained wells. Other problems are related to the spillage and leakage of brines and petroleum at oil wells in the southeastern part of the state; the mis-application of pesticides, herbicides and insecticides in agricultural areas; and the improper siting and operation of solid and liquid waste disposal facilities. Some minor ground water problems are also associated with the excessive use or improper storage of highway de-icing salts.

The dissolved solids concentrations in Ohio's streams range between 120 and 2,500 milligrams per liter (mg/l). The higher concentrations are found in the Tuscarawas, Cuyahoga and Grand Rivers and in other stream reaches below major municipal and industrial outfalls or in areas subjected to diffuse source runoff.

Of the 23,000 miles of principal rivers downstream of major urban areas in the state that have been monitored, 16,000 miles, or 70 percent of these streams, meet the current water quality standards. Where problems do exist, they are frequently caused by inadequate municipal wastewater treatment at facilities that need to be upgraded or expanded, or by combined sewer overflows. Substantial improvements in surface water quality have resulted from the development of pretreatment regulations for industrial waste discharges to municipal sewerage systems. Violations of the state's water quality standards occur most often in dissolved oxygen levels; ammonia nitrogen concentrations; the numbers of fecal coliforms; and the levels of heavy metals such as lead, zinc, and cadmium.

Acid mine drainage is a major cause of water quality problems throughout the Appalachian Coal Basin in the eastern United States. In Ohio this region extends in a band approximately 50 miles wide in a southwesterly direction from the east-central to the south-central parts of the state. Acid drainage from abandoned and improperly operated or reclaimed coal mined lands causes a loss of water for domestic and industrial uses; the degradation of water quality for recreational purposes; a lethal impact on the aquatic life in a stream; and an accelerated deterioration of highways, railroad bridges and electrical transmission lines and towers. Drainage from abandoned coal mines, both surface and underground, has impacted around 1,500 miles of streams in 27 counties in southeastern Ohio.

Approximately 370,000 acres of abandoned strip mines, 7,000 acres of coal refuse piles and 3,000 underground mines are contributing to this problem. It has been estimated that four billion dollars would be needed to reclaim the abandoned mines and refuse piles throughout Ohio. Projected revenues from severance taxes earmarked for abandoned mine reclamation come to about ten million dollars annually. Obviously, the technologic problems and the economic costs associated with the control of acid mine drainage will continue to keep this a major problem of water quality in southeastern Ohio for years to come.

Little detailed information is available on the impacts that diffuse sources of pollution, such as agricultural and urban stormwater drainage, have on the quality of water in Ohio's inland streams. One concern with non-point pollution is the sediment that is dislodged from the land surface and carried to the streams. Of greater concern are the pollutants, such as the nutrients, heavy metals and toxic organic substances, that enter the streams attached to the sediments. There has been no need for intensive, non-point source control programs to meet water quality standards where Ohio waters drain into the Ohio River; but several studies are underway in the Lake Erie drainage basin to define the role of agricultural drainage on the water quality in the lake. Much more research and many more demonstration projects on the best management practices for agriculture, silviculture, mining and urban runoff control must be conducted before this problem is fully understood and control measures can be instituted.

The trophic status of several lakes and reservoirs in Ohio has been studied; and the results suggest that the lakes and reservoirs in the sandstone bedrock areas of the state generally have lower trophic levels than those in the limestone bedrock areas or glaciated regions. Water quality was generally good to excellent in most of the lakes and reservoirs surveyed. However, excessive concentrations of copper and other heavy metals, bacteria and other pollutants that are normally associated with urban activities were identified in some of the lakes.

Recent studies on Lake Erie indicate that there has been a reduction in several key pollutants and a gradual, but steady, improvement in the water quality in the Lake during the past few years. Phosphorus is a major pollutant which results in the excessive growth of algae and other aquatic plants. As these plants die and decay, they deplete the oxygen resources of the Lake. The construction of facilities to remove phosphorus at the municipal wastewater treatment plants which discharge directly to Lake Erie has been a major factor in the reduction of phosphorus loadings and of the subsequent reduction of the anoxic areas within the Lake. Additional work on the control of phosphorus from both diffuse sources and point sources needs to be accomplished, but a significant start has been made.

Bacteria levels have been reduced in the nearshore zones where municipal wastewater treatment facilities have been constructed. This has permitted regulatory agencies to re-open bathing beaches which were often closed during the period between 1960 and 1970. Concentrations of mercury and pesticides have been reduced substantially, principally because of the federal bans that have been instituted on their manufacture, use and disposal. PCB remains a major challenge, as does the control of sediment and the nutrients, fertilizers and organic chemicals that are attached to it.

Fish populations, including the walleye pike, are beginning to increase again in the lake; but the quality and diversity of fish is still far from what they were in the past. Thermal pollution is a localized problem in some near-shore areas. However, as closed cycle cooling is required on all power generation facilities, the extent of this problem will diminish.

PROGRAM GOALS AND PRIORITIES

The Water Resources Center at The Ohio State University encourages and supports research that is directed at providing information needed to solve the major water problems at the local, state, regional and national levels. The research program at the Center includes basic or fundamental research, problem oriented or applied research, and information dissemination and technology transfer activities.

During FY 1982, the Center, in cooperation with several groups of water-related agencies and officials throughout the State prepared a prioritized list of Ohio's major water resources problems. Based upon this analysis, the following ranking of these problems was developed:

1. POLLUTION FROM DIFFUSE SOURCES - including agricultural runoff; urban runoff; runoff from on-site waste disposal systems; runoff from active, reclaimed or abandoned coal and strip mines.

2. CONTAMINATION OF DRINKING WATER SUPPLIES including surface and ground waters for both urban and rural uses by diffuse and point sources, and by the disposal of toxic and hazardous wastes on the land.

3. TOXIC AND HAZARDOUS WASTE DISPOSAL - including their control, treatment, disposal and impact upon land, water and air resources.

4. POLLUTION FROM POINT SOURCES - including municipal and industrial sources not yet in compliance with their NPDES permits.

5. IMPACTS OF FLOODING AND DRAINAGE - including flood damages, the use of flood plains and alternative structural and non-structural means of controlling floods and reducing flood damages.

6. IMPACTS OF WATER RESOURCES DEVELOPMENTS - including the impacts on various land uses caused by structural and non-structural water resources developments such as the extension of water mains and sewers into rural areas; flood control projects; hydro-electric power generation; water-based recreation; etc.

7. INSTREAM FLOWS NEEDS - including interrelationships among water quality, water quantity and land use practices on the instream flow needs for fish, wildlife, and recreation and the optimum development and protection of these instream uses.

8. IMPACTS OF SYNTHETIC FUEL DEVELOPMENT - including requirements for water and impacts of the disposal of wastes from these processes into waters and onto the land.

9. IMPACTS OF ATMOSPHERIC POLLUTION - including the effects of acid precipitation and atmospheric fallout on water quality and the environment.

10. ALLOCATION OF WATER RESOURCES - including the development of contingency plans for the allocation and conservation of limited water supplies among competing water users during periods of low stream flows.

Subsequently, the Directors of the Water Resources Research Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin's met to identify from their State problems the major water resources research priorities for the Region. A listing of these priorities is included at the end of this Section of this Report. The focus of the 1988 Ohio Water Research Institute Program will be directed at some of these crucial needs and at an assessment of the institutional/legal constraints in the development of programs to attempt to control non-point sources of pollution.

The project by L. S. Fan entitled "Optimun Design of Fluidized Bed Bioreactors for Wastewater Treatment" explored the design criteria for an innovative two-stage fluidized bed bioreactor in which the three major processes of cell immobilization, biodegradation and biofilm control were combined in a single unit. This wastewater treatment process is felt to be a substantial evolution in the operational technology of bioreactor design; and the successful completion of this project could result in the development of an innovative, reliable and considerably less costly wastewater treatment system. Dr. Fan held a Section 105 grant from the United States Geological Survey for a related project entitled "A Novel Two-Stage, Three-Phase Fluidized Bed Bioreactor with Immobilized Living Cells for Wastewater Treatment Applications".

Drs. Traina and Logan of The Ohio State University Agronomy Department, were specifically studying the potential impacts that interactions and reactions between herbicides and existing humic materials have on the fate and transpórt of the herbicides in the groundwater.

Dr. Gordon's project was a cooperative effort involving the Ohio EPA, the Ohio DNR and the Nature Conservency in examining and assessing the potential institutional and legal constraints that might hinder the development of programs for the management of non-point sources of pollution.

The technology transfer programs of the Water Resources Center continued to disseminate information about the water resources of Ohio to the local and state decision-makers, and provided technical assistance to help resolve some of the state's major water problems.

Training on these research projects was provided at two universities, to nine graduate students in the disciplies of Agricultural Engineering, Agronomy, Chemical Engineering, Civil Engineering, City and Regional Planning, Geography and the School of Natural Resources. In addition, an undergraduate student from Agronomy gained practical knowledge and training by working on these projects.

<u>Regional Research Priorities</u>
Great Lakes - Upper Mississippi - Ohio River Region

A. **Groundwater contamination**

1. Track pollutants through the vadose zone to the groundwater and determine their rate of dissipation in the aquifer.

2. Assess the impacts of the disposal of municipal and industrial wastes and effluents on groundwater systems.

3. Evaluate sources of recharge of the principal aquifers in the region.

4. Determine the effects of the storage of waste heat in aquifers on groundwater quality.

B. **Pollution of lakes and streams from non-point sources**

1. Assess relative effectiveness of non-point pollution control "best management practices" to meet the demands of P.L. 92-500.

2. Evaluate the effects of atmospheric fallout and precipitation (acids, toxic metals and hazardous trace organics) on public health and the aquatic environment.

3. Estimate the effects of drainage from land use activities in urban areas on surface water quality.

4. Model sediment transport processes and devise techniques for determining sediment delivery ratios.

5. Determine the relative effectiveness of voluntary programs enhanced by various incentives and regulation as mechanisms of implementing non-point pollution control.

6. Predict the impacts that agricultural technologies will have on surface and groundwater resources.

C. Adverse water resources impacts of energy production and mining.

1. Evaluate the impacts that drainage from mining activities will have on the incursion of acids, toxic metals, radio nuclides and hazardous organic compounds into the environment.

2. Assess atmospheric and aquatic pollution from coal-fired electric generation plants.

3. Assess legal, economic, environmental and social impacts and develop means for resolving water user conflicts associated with siting, constructing and operating energy conversion facilities and mining operations.

4. Examine the potential benefits, public and environmental, from the reclamation of heated waters from power generation.

D. Potential insufficiency of waters for agriculture and rural communities

1. Determine optimal water requirements for crop production and develop practical methods for irrigation scheduling.

2. Evaluate criteria for establishing minimum requirements for the drainage of imperfectly drained soils of the region.

3. Develop water conservation practices and methods for holding and temporarily storing surface and drainage waters for reuse in periods of seasonal suboptimal precipitation.

E. Loss and degradation of water based fish and wildlife habitat

1. Define the functional and economic value of wetlands including ecological and hydrological mechanisms that influence their integrity.

2. Develop acceptable mechanisms, including incentives and legislation, for preserving publicly and privately owned wetlands.

3. Determine the quality and quantity of instream flow necessary to maintain an active and viable aquatic biota.

4. Determine the potential and incentives needed to increase wildlife and waterfowl production on private lands.

F. Miscellaneous

Develop the relationship between commercial/commodity and recreational use of the major lake and river systems of the region. Research emphasis should be placed on development of sufficient water-based recreational facilities in urban settings.

SYNOPSIS

Project Number: 02

Start: 07/87 (actual)
End: 06/89 (actual)

Title: Optimal Design of Fluidized Bed Bioreactors for Wastewater Treatment

Investigator: Fan, Liang-Shih, The Ohio State University, Columbus

COWRR: 05D Congressional District: Fifteenth

Descriptors: Fluidized bed process, biological waste treatment, phenol, optimal reactor design

Problem and research objectives:

Stringent demands and regulations on drinking water quality and on pollution control has created a need for a more efficient and economical waste water treatment system.

Fluidized beds are considered to be one of the most promising technologies for wastewater treatment processes due to their intrinsic operational advantages. Three aspects of these processes, (immobilization, biodegradation, and maintenance of bioparticle properties) are included in the fluidization technology for wastewater treatment applications. Potential problems encountered in fluidized bed bioreactor systems are: the length of time required for biofilm cultivation before start-up; the need for frequent monitoring of particle replenishment; and quality control of the biofilms attached to particles. Thus, to improve treatment effectiveness, an optimal design for fluidized bed bioreactor systems is necessary.

A novel, two-stage fluidized bed bioreactor was designed to significantly improve the efficiency and economy of wastewater treatment. It combined the three involved processes into a single unit and eliminated the inefficient steps found in most bioreactor systems.

The objective of the research was to explore and test the design of the two-stage fluidization bed bioreator for high efficiency and cost effectiveness. The ultimate goal of the research was to develop an innovative, reliable, and effective water treatment system which could be extended to a variety of biological process applications.

Methodolgy:

Experiments conducted during the research consisted of: (1) characterizing the bioparticle separation between the stages of the bioreactor, (2) testing the efficiency of the biofilm control device, and (3) conducting biological wastewater treatment in the two-stage bioreactor and characterizing its overall performance.

The particle separation was studied by using two different sizes of activated carbon particles, 307 and 714 um. Several separation devices, which were located between the two stages, were tested individually at liquid flow rates from 1 to 10 GPH (1.05 to 10.52 cm^3 sec) and gas flow rates from 3 to 11 SCFH (23.6 to 86.5 cm^3/sec). The criterion for selecting the separation device is that the mechanism of particle separation be characterized by the liquid linear velocity through the separation device. A hydraulic biofilm removal device was used to control the biofilm. The biofilm removal efficiency was measured at various gas flow rates. Several configurations of the two-stage fluidized bed bioreactor system were attempted, which considered energy requirements for biofilm control as well as particle flow between the first and second stage of the bioreactor.

Start-up behavior of the two-stage fluidized bed bioreactor as well as steady state and dynamic experiments were also studied. Phenol was selected as the model substrate because its inhibitory biodegration kinetics is representative of several toxic pollutants. The air flow rate was set at 8 SCFH (62.93 cm^3/sec) to ensure that the oxygen supply is sufficient and the liquid flow rate was 5 GPH (5.26 cm^3/sec). Measurements of biofilm thickness, particle holdup, and substrate concentration in both stages are needed to study the behavior of the two-stage bioreactor. Particle holdup was obtained by using free flow method and biofilm thickness was measured by microscope visualization. Phenol concentrations were determined by the 4-aminantipyrine colorimetric method.

Principal findings and significance:

The study reveals that by controlling the linear liquid velocity through the separation device, the particles with smaller terminal velocity in the first stage can be successfully transported into the second stage. By applying the particle separation device, the maximum thickness of biofilms on the particles in the first stage can be properly adjusted.

The performance of the biofilm removal device was found to be dependent upon the gas flow rate and biofilm thickness of bioparticles. A 10 SCFH injecting gas flow rate was required to achieve about 15% biofilm removal efficiency. It was found that by controlling the biofilm thickness in the second stage of the bioreactor without greatly disturbing the total biomass content is an efficient way to operate these devices. Phenol biodegration experiments were conducted to testify the effectiveness of the two-stage fluidized bed bioreactor. The results showed that the two-stage bioreactor outperformed other conventional bioreactor systems as well as traditional fluidized bed bioreactors. Biodegradation rates up to 7.5 g-phenol/m^{-3} · hr. can be achieved which is almost 1.5 times of those of traditional fluidized bed bioreators. In addition, for long-term operation, the two-stage fluidized bed bioreactor system eliminated frequent interruption which is needed to maintain normal operations in traditional fluidized bed bioreators.

A comprehensive mathematical model was developed to simulate behavior of single-stage fluidized bed bioreactors and to establish design criteria for optimum operation of two-stage bioreactors. The development of the two-stage fluidized bed bioreactor provides a unique technology for wastewater treatment processes.

Publications and professional presentations:

(1) Fan, L-S, J-W Tzeng, and W-T Tang, "A Novel Two-Stage Fluidized Bed Bioreactor with Immobilized Living Cells for Biological Processing," paper presented at the AIChE 1988 Annual meeting, November 27 - December 2, Washington, D.C. (1988).

(2) Wisecarver, Weith D. and Liang-Shih Fan, "Biological Phenol Degradation in a Gas-Liquid-Solid Fluidized Bed Reactor, Bioeng., 33, 1029-1038 (1989).

M. S. Theses:

None

Ph. D. Dissertations:

Tang, W. T., "Hydrodynamics, Mixing, Gas-Liquid Mass Transfer, and Biological Applications of a Three-Phases Fluidized Bed of Low Density Particles," (1988).

Training:

One Ph. D. and one Master's student

SYNOPSIS

Project No.: 03

Start: 07/87
End: 06/89

Title: Application of Gaming and Decision Analysis to the Assessment of Legal/Institutional Arrangements for Nonpoint Pollution Control

Investigator: Gordon, Steven I., The Ohio State University, Columbus

COWRR: 06E Congressional District: Fifteenth

Descriptors: Decision making, gaming analysis, non-point pollution control institutional constraints, geographic information system, simulation modeling

Problem and research objectives:

Watersheds dominated by both agricultural and urban land uses face significant problems from nonpoint water pollutants. Yet, our regulatory institutions have inadequately addressed this problem in terms of possible standards and controls, monitoring activities and enforcement mechanisms. Part of the problems with controlling these pollutants can be attributed to the fragmentation of responsibility among many local, regional, state and federal organizations/agencies. Lacking clear authority, many agencies appear to ignore the problem or to consign it a secondary priority resulting in water quality degradation. They are averse to taking the risks necessary to solve the problem and thus seek to avoid the potential controversy which might arise. The present research has as its primary objective the assessment of the impacts of agency personnel and government officials on the administration of nonpoint pollution abatement programs. A case study in the Big Darby Creek Basin in Ohio was used to help define the nature of these institutional/legal, and management problems. Several techniques were tested as methods for assessing the nature of the problem. A secondary objective is to use the results to educate local, state and federal officials on the nature of these administrative and legal problems and on possible mechanisms to help curb the nonpoint pollution problem.

Methodology:

The research involved the application of several techniques. First, a general questionnaire was used to determine the nature of the on-going agricultural nonpoint pollution control programs in the study area. The questionnaire was administered to a sample of 18 federal, state and local agency personnel representing those who deal with nonpoint pollution programs in the five Ohio counties that are part of the Big Darby Creek Basin.

A physical model of the projected nonpoint water pollution impacts of different management/land use combinations was assembled using the resources of a related project. The Agricultural Nonpoint Source Pollution Model (AGNPS) was used to project the potential impacts of various land use and management scenarios. These data were incorporated in some of the later analyses.

A second questionnaire was then assembled which used decision analysis techniques to isolate respondents reactions to several different legal/institutional arrangements for nonpoint pollution control programs. The questionnaire asked respondents to make an allocation of new monies to three hypothetical farm programs: one in business management, one on nonpoint pollution, and one to improve farm productivity. In order to assess the impact of changing political climate on the administrators, a variation in the instructions was given reflecting a neutral, pro-management program and pro-nonpoint pollution program stance by state and local officials. Respondents were also asked some general questions concerning their attitudes toward environmental problems and a set of questions aimed at defining their general responses to locus of control questions (i.e how much control they generally feel toward events.)

The final research step was to design a computerized game Save the Big Darby, based on the results of the other research. The game is to be used as both a research and educational tool- further gauging responses to the problems posed by managing nonpoint water pollution and educating participants to the nature and extent of the problem and its potential solution.

Principal findings and significance:

The research has shown that the division and structure of the authority to control the agricultural nonpoint pollution has resulted in a relatively ineffectual program. In our sample area, 5 percent or less of the farmers participate in the programs aimed at curbing the nonpoint pollution problem. This is in spite of the fact that the respondents in out sample almost unanimously agree that this is a major problem impacting this area.

When faced with decisions with respect to new program allocations, a significant proportion of the respondents indicated a strong desire to conform with local political opinion, regardless of their feelings on the importance of the environmental problems. Thus, a significant number of the respondents change their allocation of monies to and from the hypothetical nonpoint pollution program to match the bias they are told is held by state and local officials. This finding is extremely important in terms of the future structure of nonpoint pollution programs. The current structure of related programs has personnel dividing their time among a number of pollution and other farm management tasks. If they react so strongly to political incentives, this implies that pollution control programs will get much less attention unless the programs are explicitly structured to force a particular commitment.

Simulation modeling of the agricultural pollution levels in the basin was used to help formulate a set of policy options illustrative of the nature of what must happen to improve water quality in the basin. The Agricultural Nonpoint Source Pollution Model or AGNPS was used for the simulations. Computer software linking the model with a Geographic Information System and linking the output with a standard spreadsheet allowed the exploration of a large number of options. The most significant findings indicate that certain land should be taken out of agricultural production altogether while other acreage can be converted to conservation tillage and no-till cropping and meet many of the water pollution control goals for the basin. The exception to this is for nitrogen levels which apparently cannot be reduced without controls on fertilizer application rates.

The major findings were used to produce a simulation game called Save the Big Darby. Players are given the objective of meeting some water quality goals for the basin for sediment, nitrogen and phosphorous loads. They then "run" a model which shows them in numeric form and in the form of a map on the computer screen, whether or not they have met the standards. The base run illustrates the major existing problems. The game then allows them to change the land use mix and cropping practices and shows them the impacts of those decisions on water quality. The game has been tested with a small group of decision-makers successfully and will be revised and used with a larger group in the future.

Publications and professional presentations

Steven I. Gordon and John W. Simpson, "Use of a Geographic Information system with a Nonpoint Water Pollution Model for Planning an Agriculturally Dominated Watershed: A Case Study on the Big Darby Creek Watershed". Presentation to the joint meeting of the Water Resources Center Seminar and Bio-OHIO, March, 1989.

Steven I. Gordon and John W. Simpson, "Using Computers to Simulate Nonpoint Pollution Problems", presentation at the American Planning Association Conference, Columbus, OH, May 1989.

Steven I. Gordon, "Linking a Geographic Information System with a Nonpoint Pollution Model" Paper to be presented at the Association of Collegiate Schools of Planning, Portland, OR, October 1989.

M. S. Theses: None

Ph. D. Dissertations: Ruslan Rainis - Linking Land Capability Analysis with Simulation Modeling for Nonpoint Water Pollution, OSU, Department of City and Regional Planning, in progress.

SYNOPSIS

Project Number: 04

Start: 07/87 (actual)
End: 06/89 (actual)

Title: Effect of Complexation by Soluble Humic Substances on the Aqueous Transport and Chemistry of Pesticides

Investigators: Traina, Samuel J. and Terry J. Logan, The Ohio State University, Columbus

COWRR: 05B   Congressional District: Fifteenth

Descriptors: Epidemiology, insecticides, ion exchange, percolation, rainfall-runoff processes, reverse osmosis

Problem and research objectives:

The public and scientific communities are concerned about contamination of surface and ground water by synthetic organic solutes because of the health risk these contaminants pose. Many organic solutes form strong aqueous complexes with naturally occurring, dissolved organic matter (NDOC). These complexes can be a large part of the total pesticide in the water.

It has been shown that NDOC complexes enhance the water solubilities of the "hydrophobic" compounds, reduce their biotoxicities and change their rates of bioaccumulation. Typically complexation results in decreased adsorption to soil surfaces and increased flows in porous soil. In order to understand and predict the toxicity, the chemical behavior, and the transportation of pesticides in natural environments more information of the factors influencing the nature and extent of NDOC-pesticide complex formation is needed.

Most studies of pesticide-NDOC complexes have been restricted to model systems with solution compositions unlike those typically found in nature. Variations in the ionic composition of the water environment effects the complex formations. By examining the effects of the solution composition (the cation content, NDOC type and concentration) on the formation of pesticide-NDOC moieties, and the subsequent effects on pesticide solubility, volatility and adsorption by soil; the objectives were to:

1. Determine the effects of dissolved cations, pH, and ionic strength on the binding of nonpolar organic solutes by dissolved organic matter.
2. Determine the effects of variations in cation composition on the structural conformations of dissolved organic matter.
3. Relate cation induced changes in nonpolar organic solute-dissolved organic matter complex formation, to changes in the colloidal structures of the dissolved organic matter.

Methodology:

To measure the binding of organic solutes by NDOC, fluorescence quenching measurements have been used. In this study, it was used to examine the effects of ionic strength H^+, NA^+, and Al^{3+} on the complexation of naphalene and other model nonpolar organic solutes, by water soluble organic matter (WSOC), and by soil humic acid (HA). This method was found to give highly reproducible and rapid measurements of organic solute binding by WSOC and HA, thus emphasis was given to this specific technique. This technique was used to ascertain the effects of inorganic cationic composition on the binding of organic solutes by naturally occurring dissolved organic matter. This method required that the study be limited to those molecules which exhibit intrinsic fluorescence. It was necessary to choose naphthalene and other model organic solutes as fluorescent analogues of nonfluorescent pesticide molecules. The model organic molecules chosen (polycyclic aromatic hydrocarbons, PAH) are common parent molecules of many pesticides. Thus these mole-cules provided direct information on the behavior of many pesti- icides. These molecules are also major aquatic pollutants themselves and warrant further study.

Preparation of dissolved organic carbon

The dissolved organic carbon used consisted of 1) water soluble organic carbon (WSOC) extracted from the Carlisle muck soil (euic, mesic typic medisaprist, northwest Ohio), after Traina et al (1989); 2) Carlisle humic acid, obtained with strong alkali-acid extractions after the methods sanctioned by the International Humic Substances Society (IHSS); and 3) a commercial humic acid obtained from Aldrich Chemical Company. Additional reference humic acids were obtained from the IHSS, but as this work is continuing, it will not be discussed in this report.

All dissolved organic matter was dialyzed against Na-saturated, Chelex 100, cation exchange resin, to convert the acid functional groups on the organic polymers to Na-form.

Aqueous PAH solutions were prepared by suspending excess crystals or either, naphthalene, anthracene or pyrene in HPLC grade water, in borosilicaté glass bottles for 24 hours, at 298 K. These suspensions were passed through 0.2 micron, polycarbonate membrane filters. The filtrates were collected and stored in amber, borosilicate bottles. Fresh filtrates were prepared for each experiment.

The effects of cation valence on the formation of PAH-dissolved organic matter complexes were examined by reacting aliquots of stock aqueous PAH solutions with aliquouts of dissolved organic matter, in the presence of either $NaClO_4$, $Ca(ClO_4)_2$, or

$Al(ClO_4)_3$, at 298 K. After 2 hours, the fluorescence of each PAH was measured, and analyzed with the Stern-Volmer equation (Traina, et al., 1989).

In all cases, when dissolved organic matter concentrations were increased, it resulted in a decrease in the PAH fluorescence, indicating formation of an aqueous complex between the PAH and the dissolved organic polymers. For all PAH-dissolved organic matter combinations, increases in cation valence resulted in decreases in the conditional equilibrium constant for the formation of PAH-dissolved organic matter complexes (Table 1).

Concomitant with a decrease in complex formation was the appearance of coagulated organic matter colloids. Thus increases in the valence of the counter-ions present in aqueous solutions results in an increase in the amount of coagulation of dissolved humic substances and a concurrent decrease in the formation of aqueous complexes between organic matter and nonpolar organic solutes such as PAH. This phenomena is likely due to a reduction of the total surface area of the humic and fulvic acid polymers that are exposed to the aqueous solution, which causes a decrease in the number of hydrophobic sites available to react with the nonpolar organic solute (Traina et al., 1989).

This research of nonpolar organic solute-dissolved organic matter interactions is significant because:

1. previous laboratory studies which have examined the formation of nonpolar organic solute-dissolved organic complexes in dilute, monovalent electrolytes have likely overestimated the extant of complex formation; and

2. natural variations in cation valence and concentrations do occur in surface and ground waters, thus the interactions of PAH and other nonpolar organic solutes with dissolved humic substances will be dependent upon the chemistry of the local aqueous environment.

<u>Publications</u>:

Traina, S. .J., D. A. Spontak, and T. J. Logan, 1989. Effects of cations on complexation of naphthalene by water-soluble organic carbon. J. Environ. Qual. 18:221-227.

Traina, S. J., 1989. Applications of luminescence spectroscopy to studies of colloid-solution interfaces. Advan Soil Sci. In press.

Traina, S.J., J. Novak, N. Smeck. 1989. A UV absorbance method of estimating the percent aromatic C content of humic acids. J. Environ. Qual. In press.

M. S. Thesis:

Spontak, D. A. 1989. Effects of cations on the complexation of polycyclic aromatic hydrocarbons by dissolved humic and fulvic acids. Department of Agronomy, The Ohio State University, Columbus, OH. To be filed September 1, 1989.

Training

One student for Master's degree and one undergraduate student

Table 1. Effect of Cations on the Conditional Equilibrium Constant ($^{c}K_{oc}$) for PAH-humic substance complexes.

PAH	Humic Substance	Cation	$^{c}K_{oc}$
			(1×10^4)
Naphtlene	Carlisle WSOC	Na	7.7[a]
		Ca	7.2[a]
		Al	3.5[b]
	Carlisle Humic Acid	Na	11.2[a]
		Ca	8.2[b]
		Al	8.3[b]
	Aldrich Humic Acid	Na	14.1[a]
		Ca	7.8[b]
		Al	6.9[b]
Anthracene	Carlisle WSOC	Na	8.9[a]
		Ca	5.5[b]
		Al	5.2[c]
	Carlisle Humic Acid	Na	13.0[a]
		Ca	9.1[b]
		Al	7.2[c]
	Aldrich Humic Acid	Na	8.9[a]
		Ca	5.7[b]
		Al	4.5[c]
Pyrene	Carlisle WSOC	Na	10.3[a]
		Al	7.9[b]
	Aldrich Humic Acid	Na	32.5[a]
		Al	16.5[b]

INFORMATION TRANSFER ACTIVITIES

The Water Resources Center moved in June, 1989 to the Agricultural Engineering Building on The Ohio State University campus. This move affords opportunities to work closely with researchers in the College of Agriculture as well as the College of Engineering.

A series of tasks were continued or initiated to transfer and disseminate information developed by researchers affiliated with the Water Resources Center to a wide range of State, Federal, County and Municipal agencies; to the private sector; to the academic community and to private citizens throughout Ohio.

WATER RESOURCES CENTER LIBRARY

The Water Resources Center has maintained a library of water resources related publications since its establishment in 1965. This library has been maintained throughout the year but during the move in June, it was placed in storage until adequate space to maintain it becomes available.

Water Luncheon Seminars

The Water Resources Center continued to co-sponsor a bi-monthly Water Luncheon Seminar Program for the water resources community in Central Ohio. This program, was developed cooperatively with The Ohio Department of Natural Resources (ODNR), the Ohio Environmental Protection Agency (OEPA), the Soil Conservation Service (SCS), the District Office of the United States Geological Survey (USGS), and the Agricultural Engineering Cooperative Extension Service of The Ohio State University. More than eighty water resources professionals from Federal, State, County and Municipal Agencies, the private sector and the academic community attend each meeting to discuss current state, federal and local water policy issues, problems, programs and research results.

In addition to the growing attendance, the newsworthiness of the information transferred at these meetings is being recognized by the local media and is being transferred to the general public via the press. This year, for the first time, articles on two seminar programs were published in **The (Columbus) Dispatch**, Sunday editions in the Science Section.

The Center not only provides administrative support for the seminar series and mailing costs, but also provides financial support for rental of various media effects and meals.

The moderators, speakers, and topics that were presented during the 1988/89 program follow.

Water Luncheon Seminar, FY 1988

Date	Speaker/(Sponsoring Agency)	Topic
9/13/88	Dr. Jay H. Lehr, Director National Water Well Association (OSU Cooperative Extension Service)	The Irrigation Water Supply Potential of Ohio's Aquifers
11/8/88	Dr. E. Scott Bair Hydrogeology Professor The Ohio State University (United States Geological Survey)	Results of the N-1 and N-2 Studies of the South Well Fields in Columbus, OH
1/24/89	Mr. Vijay Rastogi B. F. Goodrich Akron, Ohio (Soil Conservation District)	ProMac Systems Use of bactericides in reclamation to control acid mine drainage
3/14/89	John W. Simpson, Professor OSU Dept. of Landscape Architecture and Steven I. Gordon, Professor OSU Dept. of City and Regional Planning (Ohio Environmental Protection Agency, the Water Resources, and the Ohio Biological Survey)	Use of Geographic Information System with a Nonpoint Water Pollution Model for Planning an Agriculturally Dominated Watershed: A Case Study on the Big Darby Creek Watershed
5/9/89	Mr. Robert Goettemoeller Chief, Water Division Ohio Department of Natural Resources (Ohio Department of Natural Resources)	Water Related Legislation Before 118th General Assembly including: Coastal Management, Dam Safety, Great Lakes Charter Initiatives, and Great Lakes Protection Fund, Flood Plain Management, Water Rights, Water Data, Urban Storm Water Management and others

The Ohio Water Atlas

In cooperation with Kent State University's Geography Department, the Ohio State University School of Natural Resources and the Water Resources Center, a preliminary survey was conducted to establish the need for a State Water Atlas. This was done by reviewing the maps that are available in the state through state and federal agencies. More than 150 maps were identified, detailed, classified, and this information was computerized for future reference. Prototypes of maps for future planning were also designed by Kent State. A meeting with the state's leading representatives in water was held to clarify the need, purpose, and direction this activity should take.

Information Dissemination Activities

The Center continues to meet with the leading water resources officials in the state to share information on current water management and policy issues; to seek continued support for the water research program and to disseminate the information and technology developed throughout the state and region.

In response to a suggestion from the Water Resources Center's evaluation team, a newsletter has been developed and publication started in FY 1988. The newsletter,**WATER**, focuses on Ohio's water research, technology, issues, legislation in process, education and Center activities. It has a wide circulation and has been well received. Mrs. Carol Moody, is the editor for **Water**, as well as the secretary to the Center.

Consultation and Collaboration Activities

The Center's Director has continued to meet with the leading water resources officials in the state for the purposes of consultation and collaboration to identify the major water problems and the research needs of the state and region; to share information on current water management and policy issues; to seek continued support for our water research program and to disseminate the information and technology developed through this program and others at the universities throughout the State and Region.

The Director has been appointed by the Governor of Ohio to serve on the Ohio Water Advisory Council, a statutory commission that advises the Water Division of the Ohio Department of Natural Resources. The Mayor of the City of Columbus appointed the Director to the Solid Waste Recycling Task Force Committee.

The Director continues to serve on the Board of Directors to the Ohio River Basin Research and Education Consortium and is a member of the 1989 Symposium planning committee.
The Director is the Lead Delegate to the Universities Council on Water Resources (UCOWR) and is a past member of the Board of

Directors; he serves on the Water Programs Public Advisory Group to the Ohio Environmental Protection Agency and is a member of the Toxics Technical Advisory Committee; and he is a member of the Ohio Inter-Agency Water-Use Data Coordinating Committee for the Ohio District of the U. S. Geological Survey.

COOPERATIVE ARRANGEMENTS

Program Development

Three of the research projects that were initiated in the FY 1987 State Water Resources Research Program were continued in the FY 1988 Program. Because of the limited amount of uncommitted federal funds available to support new research efforts, the Water Resources Center's Advisory Committee felt it would be inappropriate to conduct a state-wide solicitation for only one new project proposal for the FY 1988 Program. A letter was mailed which indicated this fact and suggested alternative sources of funds to support water related research. This was mailed to more than forty public and private colleges throughout Ohio. Central State University, the only historically black university in the State qualified to participate in the program, also received this letter. A copy was sent to the following faculty and administrators at Central State University: Dr. Arthur Thomas, President; Dr. Thyrsa Svager, Vice President & Provost; Dr. Henry Smith, Director, International Center for Water Resources Management.

The process used to initiate proposals for the 1987 program was: a call for pre-proposals for the Fiscal Year 1987 State Water Resources Research Program was sent to research administrators and qualified faculty investigators at over 40 private and public colleges and universities throughout Ohio on November 15, 1986. This announcement, contained the research priorities identified for the major water problems in the Great Lakes, Upper Mississippi and Ohio River Basins by the Water Resources Research Institutes in the Region.

The announcement also required interested researchers to request a copy of the Preliminary Proposal Application Form which was to be completed and returned to the Water Resources Center in mid-January, 1987. More than 250 names were included on the distribution list. In addition to this general mailing, a separate letter was sent to the President of Central State University, encouraging him to have the faculty participate in the Program.

Pre-Proposals/Federal Guidelines

In 1987 Preliminary Proposal Application Forms were requested by and sent to thirty-one investigators and research administrators at twelve colleges and universities in Ohio. A copy of this Application Form was also requested by Teater and Associates for Central State University. Teater and Associates are the program development consultants for the recently established International Center for Water Resources Management at Central State University.

However, no Historically Black University responded. A copy of the federal guidelines for the Program was enclosed with the Form.

Evaluation/Selection Procedures

Twenty pre-proposals from eight universities and colleges throughout the state were submitted for evaluation and consideration. These pre-proposals were subjected to a review by all of the members of the Water Resources Center's Advisory Committee. In addition, the twenty pre-proposals were distributed to the various divisions within the three principal state and federal water-related agencies in the State by the representatives of these agencies who serve on the Advisory Committee, requesting that the divisions review the proposals. The three agencies included in this evaluation were the Ohio Department of Natural Resources, the Ohio Environmental Protection Agency, and the District Office of the United States Geological Survey.

The results of these reviews were presented at a meeting of the Advisory Committee where this panel selected ten of the pre-proposals and instructed the Center's Director to request fully developed proposals from the investigators for the Committee's further consideration.

Only nine of the selected pre-proposals were developed more fully and were re-submitted for consideration. The proposals were subjected to a technical review by at least three qualified evaluators selected by individual members of the Water Resources Center's Advisory Committee. Many of these evaluators were from state and federal agencies and from universities other than The Ohio State University.

The results of these reviews were presented at a meeting of the Advisory Committee and this panel ranked the leading six proposals in the order they felt would best meet the needs and objectives of the Water Resources Center's program. The Advisory Committee then instructed the Center's Director to incorporate as many of these projects as Federal funds would permit into the FY 1987 Program and to develop a project for information transfer for the Center. There was only enough Federal monies to support four projects. In 1988 three of these projects were continued.

The membership of the Water Resources Center's Advisory Committee, which includes representatives from five colleges and eleven departments of The Ohio State University and the three representatives of the principal water-related state and federal agencies, is included in this report.

Regional Cooperative Initiatives

The three projects selected for this program had been compared in the FY 1987 Program synopses of the projects included in the programs of the other Water Resources Institutes in the Great Lakes, Upper Mississippi and Ohio River Basin to ensure that there was no duplication of efforts in the Region's research programs.

The Ohio State University has agreed to continue as a Charter Member of the Ohio River Basin Research and Education Consortium, and the Director of the Water Resources Center continued serving as one of the University's three representatives to the Consortium.

The Director has also been nominated to serve as The Ohio State University's liaison with the Center for International Water Resources Management at Central State University.

Program Management

At least once each quarter, the Director contacts the Principal Investigator on each research and information transfer project to discuss progress made during the quarter and to discuss the next quarter's plan of activities. At this same meeting budget details are reviewed and discussed, and necessary operating and reporting procedures to the Water Resources Center and to The Ohio State University Research Foundation's business office are described.

Progress Reports or Completion Reports were prepared for each Project by the Principal Investigators and were used by the Program Director to prepare the Program Final Report.

All of the investigators are urged to publish the results of their findings in the technical literature of their major disciplines and in other journals that are appropriate to the topic of their research. They are also encouraged and invited to present their findings at the Water Luncheon Seminar that is a part of the technology transfer activities of the Center.

The manuscripts that constitute the project completion reports are first reviewed by the Director of the Water Resources Center. As needed, the Director seeks the advice and council of appropriate state, federal and university scientists for methods of enhancing the value of the technical completion reports to the water-related community in the state and in the region.

WATER RESOURCES CENTER ADVISORY COMMITTEE

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17. Dr. William Mattox

UNITED STATES GEOLOGICAL SURVEY

18. Mr. Steve Hindall
    District Chief

TRAINING ACCOMPLISHMENTS

The following tabulation shows, by fields of study and training levels indicated, the numbers of individuals participating in projects that were financed in part with this grant.

Training Category	Undergraduate*	Training Level Graduate Master's Degree	Ph.D. Degree	Post - Ph.D.*	Total
College of Agriculture					
Agricultural Engineering		1			1
Agronomy	1	1			2
School of Natural Resources		1			1
Engineering					
Chemical		1	1		2
Civil		1			1
City and Regional Planning		1	1		2
Geography		1			1
	1	7	2		10